·综述与进展·

New dromaeosaurid dinosaur from the Late Cretaceous Qiupa Formation of Luanchuan area, western Henan, China

豫西栾川地区晚白垩世秋扒组一新的驰龙类化石

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Abstract: A new dromaeosaurid dinosaur Luanchuanraptor henanensis gen. et sp. nov. is erected based on the following characters: about 24 posterior serrations per 5 millimeters on the posterior carnia of teeth; the proximal and posterior extensions of the haemal arch are short and trifurcated; the elongated prezygapophyses of the distal-most caudal vertebrae wrapped the preceding vertebra and the caudal vertebrae bear a low, blade-like neural spine between the prezygapophyses; the medial surface of the coracoid is strongly concave; the shaft of the humerus is straight and the deltopectoral crest extends over almost the proximal half of the humerus. Luanchuanraptor henanensis represents the first dromaeosaurid dinosaur found outside the Gobi region and northeastern China in Asia.
Key words: Luanchuanraptor; Dromaeosauridae; Qiupa Formation; Late Cretaceous; Luanchuan, Henan

摘要: **根据以下特征**, **建立驰龙类恐龙一新属新种——河南栾川盗龙**(Luanchuanraptor henanensis gen. et sp. nov): **牙齿后缘每**5 mm**有**24**个小锯齿**; **前部背椎椎体具有小的椎体侧孔**; **后部脉弧的前后突短且为三分支**; **最后部的尾椎体的椎体前突拉长且包裹与其相邻的前部椎体**, **两椎体前突之间夹有低的刀片状的神经棘**; **乌喙骨的内面强烈凹陷**; **肱骨骨干直**, **肱骨三角脊几乎占肱骨长度的前部一半。河南栾川盗龙代表除在亚洲戈壁地区及中国东北地区之外发现的第一件驰龙类化石标本。**
关键词: **栾川盗龙**; **驰龙科**; **秋扒组**; **晚白垩世**; **河南栾川**
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Dromaeosaurid dinosaurs are small to medium sized carnivores, and they range from the Early Cretaceous to the Late Cretaceous[1]. Dromaeosaurid dinosaurs play a key role in understanding of avian origins. Some dromaeosaurid dinosaurs were covered with featherlike integumentary structures or feathers of modern aspect[2-6]. In Asia, most dromaeosaurid dinosaurs have been reported from Mongolia and northeastern China[2-3,7-9]. We herein report a new dromaeosaurid dinosaur Luanchuanraptor henanensis gen. et sp. nov. from the Late Cretaceous Qiupa Formation, Henan Province of Central China (Fig.1). It represents the first dromaeosaurid dinosaur found from outside Gobi and northeastern China.

1 Systematic Paleontology

Dinosauria Owen 1842[10]
Saurischia Seeley 1881-1888[11]
Theropoda Marsh 1881[12]
Maniraptora Gauthier 1986[13]
Dromaeosauridae Matthew and Brown 1922[14]
Luanchuanraptor gen. nov. (Figs. 2-8)

Etymology: Luanchuan, refers to the Chinese administrative unit Luanchuan County of Henan

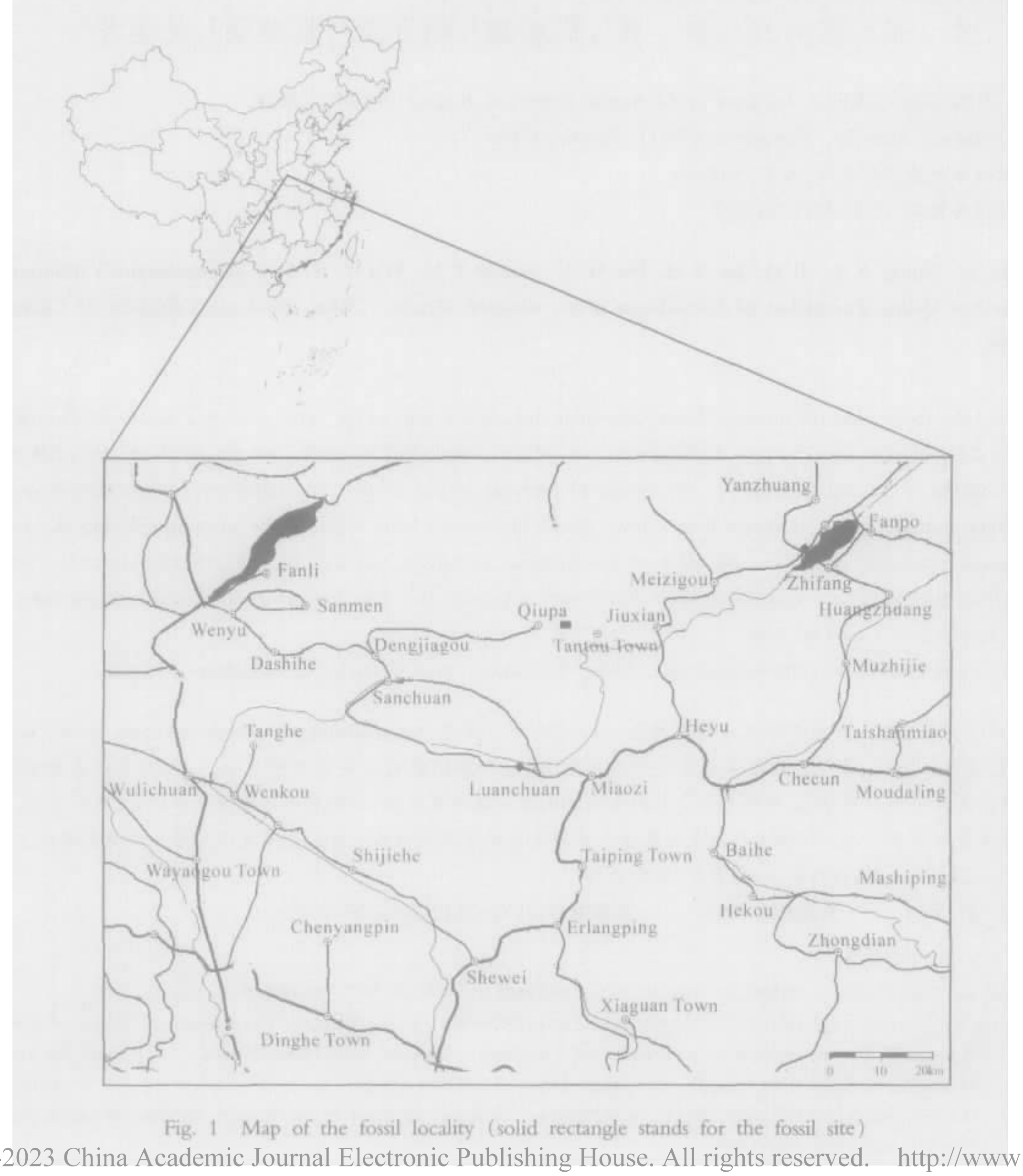


Fig. 1 Map of the fossil locality (solid rectangle stands for the fossil site)

Province, which the holotype locality belongs to; From Latin raptor, thief.

Diagnosis: as for the only species.

Species: Luanchuanraptor henanensis sp. nov.

Etymology: Henan refers to Henan Province, where the holotype site-Luanchuan administratively belongs to.

Holotype: Four nearly complete teeth; one nearly complete left frontal; one posterior cervical vertebra, one anterior dorsal vertebra (possibly the first dorsal vertebra), two anterior caudal vertebrae, two middle caudal vertebrae, 13 posteriormost caudal vertebrae, anterior, middle and posterior haemal arches, complete left scapulocoracoid, right humerus, complete right ilium and left pubis and other bone fragments (41HIII-0100). The specimen is housed at the Henan Geological Museum.

Holotype locality and horizon: Luanchuan of Henan Province; Qiupa Formation[15].

Diagnosis: A middle sized dromaeosaurid dinosaur differs from other dromaeosaurid dinosaurs in that the elongated prezygapophyses of the distalomost caudals spanning only one preceding vertebra and the caudals bear a low, blade-like neural spine between the prezygapophyses indicating an unflexible end of the tail; a distinct groove is present in the position of the neural spine in some distal caudal vertebrae; the anterior haemal arches are bridged; the proximal and posterior extensions of the posterior haemal arche are short and trifurcated with short middle process; and large, deep concavity present on the medial surface of the coracoid. The deltopectoral crest of the humerus extends over the proximal half of the humerus.

2 Description

Because all the postcranial specimens come from the same quarry, and there are no duplicated bones, these specimens are assigned to one individual. Although 9 teeth and one frontal are also found from the same quarry, only four small teeth and the frontal correspond in size to the postcranial bones. The other five teeth may belong to a large sized theropod dinosaur.

Frontal (Fig. 2-A、B、C): The left frontal preserves most of the interfrontal suture and the orbital rim. The orbital border of the frontal is curved caudolaterally. It is rugose. The distance between the interfrontal suture and the dorsal margin of the orbit is large. This indicates that the skull table flares widely over the orbits, which are directed rostrolaterally, indicating stereoscopic vision, as is the case in some troodontid dinosaurs [16]. The suture between the frontal and the orbitosphenoid is clear (Fig. 2-B). There is a round opening near the posteroventral margin of the frontal. It may be the exit of the cranial nerve IV (Fig. 2-C), as observed in Troodon formosus[17]. The unfused frontals indicate that this animal is not an adult individual. In medial view, the posterior portion of the frontal is curved dorsally and its anterior portion is nearly flat. A large, concave inner surface of the frontal indicates that Luanchuanraptor bears a large forebrain. A deep groove on the medial surface under the middle line of the frontal which extending anteriorly, should be the canal of the olfactory tract (Fig. 2-B).

Teeth (Fig. 2-D): All the teeth are compressed, blade-shaped, and distinctly curved with serrations on carnia, similar to these of other dromaeosaurid dinosaurs[18]. These teeth are isolated, therefore, it is difficult to determine their positions in the jaws. Some teeth do not bear anterior serrations. Anterior serrations are weaker than the posterior serration in some teeth. There are about 24 posterior serrations per 5 millimeters on the posterior carnia. This is similar to Saurornitholestes [19] and Velociraptor mongoliensis[20], where the posterior serration counts of the tooth is 24-26 per 5 millimeters and 25 to 26 per 5 millimeters respectively. The less distinctly curved tooth may be a premaxillary tooth. The teeth have unrestricted roots, as that of Buitreraptor[21].

Seventh incomplete vertebrae are preserved. They are assigned to cervical, dorsal and caudal positions.

Posterior cervical vertebra (Fig. 3-A): The vertebra is almost complete except it is missing the right side of the neural arch. The ventral margin of the parapophyseal facets are located at the same level of the ventral margin of the anterior articular end, thus the anterior articular end is much wider than the posterior end. The ventral margin of the anterior centrum end and the ventral margin of the neural canal are straight, thus, the shape of the anterior centrum end is trapezoidal. Both the anterior and posterior articular ends are moderately concave. The posterior articular end is rounded. A weak ventral keel is present on the centrum. An elongated pleurocoel is located posterior to the parapophyseal facet. A small opening is also present ventral to the pleurocoel. The diapophyseal facet is oval and is smaller than the parapophyseal facet. The facets of the prezygapophyses face mediolaterally. The neural arch is short and narrow anteroposteriorly. The facet of the postzygapophysis is oval and faces posteroventrally. A distinct epipophyseal process is located anterior to the posterior margin of the postzygapophysis process. The neural canal is oval in posterior view and rectangular in anterior view.

Dorsal vertebra 1. A distinct hypapophysis is present on the ventral surface near the anterior articular end (Fig. 3-B). The anterior centrum end is moderately concave and it is hexagonal in anterior view. The posterior centrum end is concave and rounded. The parapophysis is stalk-like. The parapophyseal facet is concave and round, and faces posterolaterally. The transverse process extends posterolaterally and slightly dorsally. Two large concavities are present on the lateral surface of the base of the neural arch. The anterior one, which is deeper than the posterior one, is located between the base of the prezygapophysis and anterior surface near the base of the transverse process. This similar concavity is called an excavation of neural arch by Ostrom[22], but it is much larger in Deinonychus than in Luanchuanraptor. The posterior one is located between near the lateral surface of the postzygapophysis and the posterior surface of the base of the transverse process. A deep concavity is present above the dorsal margin of the neural canal. A small distinct epipophysis is present on the dorsal surface of the postzygapophysis and extends posteriorly beyond the posterior margin of the postzygapophysis. The neural spine is not well-preserved, but the broken surface indicates that it is anteroposteriorly short and low. A small, round pleurocoel is present on the middle of the centrum and another small opening is present near the base of the hypapophysis.

Anterior caudal vertebra 1: The left transverse process is missing. The transverse process is wide in anteroposterior direction (2.7cm). It occupies more than half the length of the centrum. The transverse process extends posterodorsally and slightly laterally. A shallow concavity is present near the anterior and posterior ventral surface of the transverse process. The anterior and posterior centrum ends are round and concave. Both the prezygapophyses and postzygapophyses extend beyond the articular ends. The lateral surface is nearly flat without pleurocoels. Two distinct facets for the haemal arch are present on the lateroventral surface near the posterior articular end. A deep groove is present near the posterior articular end.

Anterior caudal vertebra 2. This centrum is slightly shorter than the anterior one. The neural arch is very low. The transverse process is wide and extends posertolaterally and slightly ventrally. The ventral surface near the base of the transverse process is flat without concavity. Other characters are similar to those of the anterior caudal vertebra.

Caudal vertebra 3. This vertebra is complete. The prezygapophysis has a distinct facet and faces medially. A distinct epipophysis is present on the dorsal surface of the prezygapophysis. The prezy-

gapophysis extends anterodorsally. The transverse process is plate-like, and extends posterolaterally and dorsally. The neural spine is short anteroposteriorly and a little higher than on the anterior caudals. The anterior centrum end is concave, whilst its posterior articular end is hexagonal but convex. A distinct ventral groove is present on the middle of the ventral surface of the centrum. The short prezygapophysis indicates that it belongs to the middle caudal series.

Caudal vertebra 4. This vertebra is different from the anterior ones in that the prezygapophysis is much longer than anterior one, and it tapers distally. The transverse process becomes narrow in its middle portion and expanded distally. The neural spine is weak. The anterior centrum end is

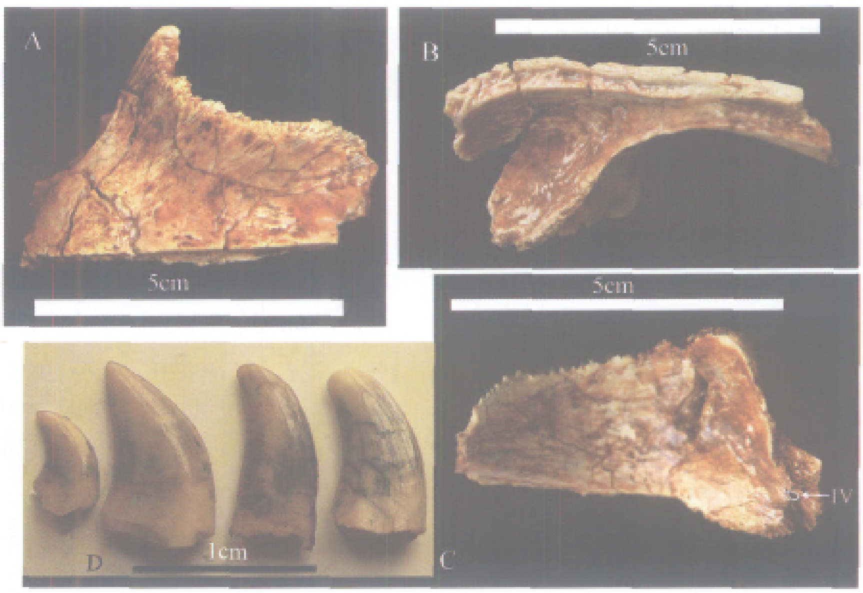


Fig. 2 The left frontal (A–C) and teeth (D) of *Luanchuanraptor henanensis* (41HIII–0100) in dorsal view (A), medial view (B), and ventral view (C)

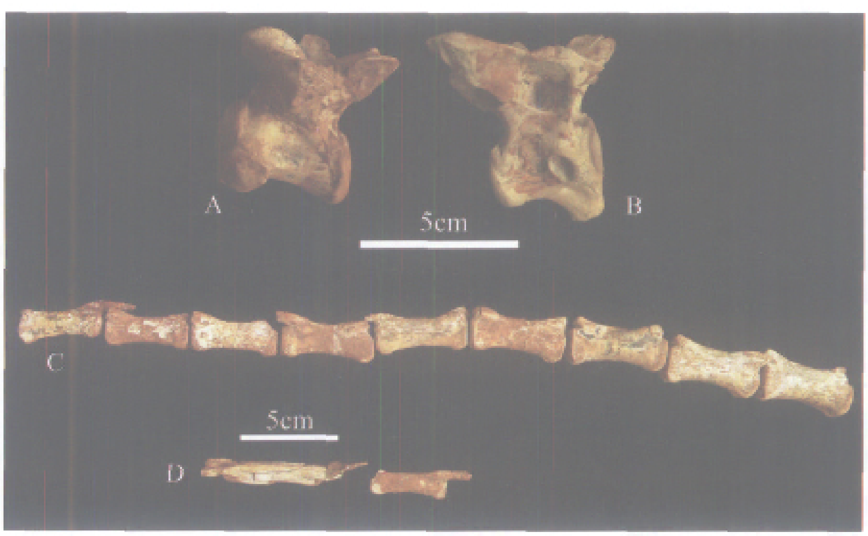


Fig. 3 Vertebrae of *Luanchuanraptor henanensis*. Posterior cervical vertebra in left lateral view (A), anterior dorsal vertebra in right lateral view (B), middle caudal vertebrae in right lateral view (C) and distalmost caudal vertebrae (D) in right lateral view

concave and its posterior articular end is convex. A deep ventral groove is present along the whole length of the centrum. The pointed prezygapophysis indicates that this vertebra belongs to the posterior caudal series.

Ten distal caudal vertebrae are preserved (Fig. 3-C), and most of them are missing their zygapophyses. All of these vertebrae are slender and with concave anterior articular ends and convex posterior articular ends. Distinct ventral grooves are present. The preserved prezygapophyses are elongated. They are similar in shape except for becoming shorter distally.

Distalmost caudals (Fig. 3-D): The distal most vertebrae are much slenderer than the anterior ones. A distinct groove is present in the position of the neural spine. A distinct groove is also present on the ventral surface of the centrum. Both centrum ends are nearly flat. Two distal most caudal vertebrae are naturally articulated. The prezygapophysis becomes widened near the contact area of the vertebrae. The postzygapophyses are usually relatively shorter than the prezygapophyses, which is similar to these of Saurornithoides jusnior[23] and Buitreraptor[21]. Anteriorly, the prezygapophyses are divided into three small branches. A shallow neural spine extends posteriorly, and overlaps the anterior part of the posterior connected caudal vertebra. A sulcus is also present along the ventral midline of the centra, similar to that of some troodontids. The posterior centrum end is nearly flat.

Ribs (Fig. 4): Three ribs are preserved, one proximal cervical rib, one posterior cervical rib, and an anterior dorsal rib. A small concavity is present on the posterior surface just ventral to the rib head. The posterior surface of the rib shaft is concave and its anterior surface is convex.

Haemal arches (Fig. 5): Three anterior haemal arches are well-preserved. They are mediolaterally flatted and Y shaped in anterior and posterior views. The shaft of the haemal arch curves posteriorly in lateral view. The haemal canal is bridged in the anterior two haemal arches, but it is open in the third one.

Middle and distal haemal arches: This haemal arch is shortened with a distinct posterior process. The distal haemal arches are not well-preserved. The proximal extensions of the haemal arches are short and trifurcated, and its posterior extensions are also trifurcated and moderately longer, unlike the case in many dromaeosaurs, which bear hyper-elongate extensions. The ventral surfaces of the haemal arches are flat. It is different from that of troodontid Sinornithoides youngi, dromaeosaurid Deinonychus[22] and other theropods, where a longitudinal, medial, shallow trough presents on the ventral surface[24]. In lateral aspect, they taper anteriorly and posteriorly, and there is no vertical extension on the midline as the case in Sinornithoides youngi[24], but differs from these of Sinornithoides youngi in that the proximal and posterior extensions of the haemal arches are bifurcated in Sinornithoides youngi, not trifurcated.

Scapulocoracoid (Fig. 6-E、F、G): The scapula and coracoid are densely fused with an obscured suture between them, similar to that of Velociraptor mongoliensis[25]. The left scapulocoracoid is missing only the central portion of the coracoid. The scapular blade is curved medially and strap-like with a short acromion process. The distal end is slightly expanded. The glenoid fossa faces posterolaterally. The coracoid is nearly rectangular in lateral view. A distinct coracoid tuber is present. The ventral margin of the coracoid is slightly convex. The posterior margin of the coracoid is thicker and curved posteriorly in lateral view. Anterodorsal to the coracoid tuber, an elongate coracoid foramen is present. The area above the coracoid tuber is concave in lateral view, but nearly flat in medially surface. Posteroventral to the coracoid foramen, a strong concavity is present on the medial surface of the coracoid, and a similar structure is also found on some Deinonychus specimens [26]. Because the bone is very thin, this part is missing.



Fig. 4　Dorsal ribs (upper two) and cervical rib (bottom) of *Luanchuanraptor henanensis*



Fig. 5　Anterior (A), middle (B) and posterior haemal arches (C), in lateral view and posterior haemal arches (D) in ventral views of *Luanchuanraptor henanensis*



Fig. 6　Right humerus and left scapulocoracoid of *Luanchuanraptor henanensis*. Humerus in anterior view (A), posterior view (B), ventral view (C) and dorsal view (D). Scapulocoracoid in medial view (E), lateral view (F), and ventral view (G)

Right humerus (Fig. 6- A、B、C、D): The humerus is almost complete except for a small portion near the proximal end. The mid- shaft of the humerus is expanded mediolaterally, and this is unusual and it may be caused by disease. The deltopectoral crest is moderately developed. It is extended across almost the proximal half of the humerus, this is different from other dromaeosaurid dinosaurs, such as Velociraptor and Deinonychus, where the deltopectoral crests are restricted to the proximal third and quarter respectively[1]. The deltopectoral crest is also restricted much more proximally in Buitreraptor gonzalezorum[21]. The internal tuberosity is strongly developed as in Deinonychus[22]. A ridge is present on the lateral surface of the humeral shaft just distal to the deltopectoral crest. Distally, the lateral condyle is larger than medial condyle. A trochlea is present on the lateral condyle which articulates with the radius. The posterior surface near the distal end is flat, and its anterior surface is depressed.

Phalanx: One phalanx is preserved. It is slender. It may be the first phalanx of the first right digit of manus.

Manual claw: one manual ungual is preserved. The tip of the claw is missing. It is moderately

curved with a distinct groove on the lateral surface. There is no lip-like process on the dorsal surface of the proximal end.

Right ilium (Fig. 7-A、B、C、D): The ilium is almost complete except for a small portion of dorsal margin and anterior margin of the anterior acetabular process. The dorsal margin of the ilium is slightly convex in lateral view. The postacetabular process is slightly longer than the anterior acetabular process. The distal end of the postacetabular process is tapered distally. The distal end of the anterior acetabular process is hook-like. A cuppedicus fossa is present on the ventral surface near the base of the anterior acetabular process (Fig. 7-C). A wide and shallow brevis fossa is present on the ventral surface of the post acetabular process. The pubic peduncle is wider than the ischiadic peduncle, and it extends ventrally beyond level of ischiadic peduncle. The lateral surface of the ilium is concave. There is no supracetabular crest.

Pubis (Fig. 8): The left pubis is well-preserved. It extends posteroventrally, rather than anteroventrally. The shaft of the pubis is twisted and the posterior surface of the lower 2/3 portion of the pubis is concave. The pubic apron forms the medial margin of the lower 2/3 portion of the shaft. Distally, the pubic foot is not developed. It is not expanded either anteriorly or posteriorly, as in the troodontid Sinornithoides youngi and dromaeosaurid Velociraptor[27].

The lateral surface near the proximal end is slightly concave. The articular surface for the ilium is triangular.

Femur: A part of the left femur is preserved, unfortunately, only the mid-shaft is preserved. It is curved posteriorly and has a distinct fourth trochanter.

3 Discussion

Luanchuanraptor is assigned to Dromaeosauridae based on the following characters: large, laterally compressed, sharpened, and recurved teeth, about 24 posterior serrations per 5 millimeters on the posterior carnia of the teeth, teeth without root-crown constriction, stalk-like parapophyses on the dorsal vertebrae[1,21], and distal chevrons with flatted ventral surfaces that extend both anteriorly and posteriorly, although it lacks the hyperelongated extensions seen in many dromaeosaurids, except for Buitreraptor, whose dorsoventrally compressed chevrons are short and bifid at both ends[21].

Luanchuanraptor differs from Bambiraptor[28-29] in the latter the scapula and coracoid are not fused, the coracoid is longer anteroposteriorly than tall dorsoventrally, the coracoid has a distinct neck, the deltopectoral crest is restricted more proximally, and the postacetabular process of the ilium is pointed in Bambiraptor[29]. Luanchuanraptor in contrast has the scapula and coracoid fused, the coracoid is nearly rectangular, the deltopoectoral crest covers almost proximal half of the humerus and the postacetabular process of the ilium is slightly pointed.

Luanchuanraptor differs from Deinonychus[22] in that posterior serration account is 16-18 in Deinonychus, whereas this number is about 24 in Luanchuanraptor; the delopectoral crest of the humerus is restricted much more proximally in Deinonychus than in Luanchuanraptor. In lateral view, the dorsal margin of the ilium is convex in Luanchuanraptor, but it is nearly straight in Deinonychus.

Although the posterior serrations on the posterior carnia of the teeth are similar in both Saurornitholestes[19] and Luanchuanraptor, the teeth crowns of Luanchuanraptor are much wider and more recurved than those of Saurornitholestes.

Luanchuanraptor differs from the basal dromaeosaurid dinosaur Microraptor[3,9] in that the anterior serrations are absent on all of the teeth in Microraptor zhaoianus[3]. The glenoid fossa of scapulocoracoid faces posterolaterally in Luanchuanraptor, but that of Microraptor gui faces laterally[9].

Luanchuanraptor differs from Buitreraptor[21] in that the prezygapophyses of caudal vertebrae only



Fig. 7　Right ilium of *Luanchuanraptor henanensis* in lateral view (A), ventral view (B), medial view (C), and dorsal view (D)



Fig. 8　Left pubis of *Luanchuanraptor henanensis* in lateral (A), anterior (B), and posterior views (C)

overlap half of the preceding vertebra, the dorsoventrally compressed chevrons are bifid at both ends and the deltopectoral crest of humerus restricted more proximally in Buitreraptor, however, the prezygapophyses of caudal vertebrae overlap whole length of the preceding vertebra, the dorsoventrally compressed chevrons are trifurcated at both ends and the deltopectoral crest of humerus restricted almost half of the humerus in Luanchuanraptor.

Luanchuanraptor also shares some characters, such as the more distal chevrons bearing cranial extensions, short chevrons and prezygopophyses of caudal vertebrae with troodontid dinosaurs, supporting the idea that dromaeosaurid dinosaurs are the sister group of troodontids, which forms a monophyletic Deinonychosauria[30-31,16].

4　Conclusions

Due to the lack of complete skull in Luanchuanraptor, it is difficult to compare Luanchuanraptor with other dromaeosaurid dinosaurs known from skulls. However, Luanchuanraptor bears some characters, which are diagnostic of dromaeosaurid dinosaurs, especially the stalk- like parapophyses on dorsal vertebrae and elongated caudal zygopophyses. Luanchuanraptor is the first dromaeosaurid skeleton found outside of the Gobi and northeastern China in Asia.

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